

Fuzing and the MEMS Dilemma

36th Annual NDIA Gun &
Ammunition Symposium
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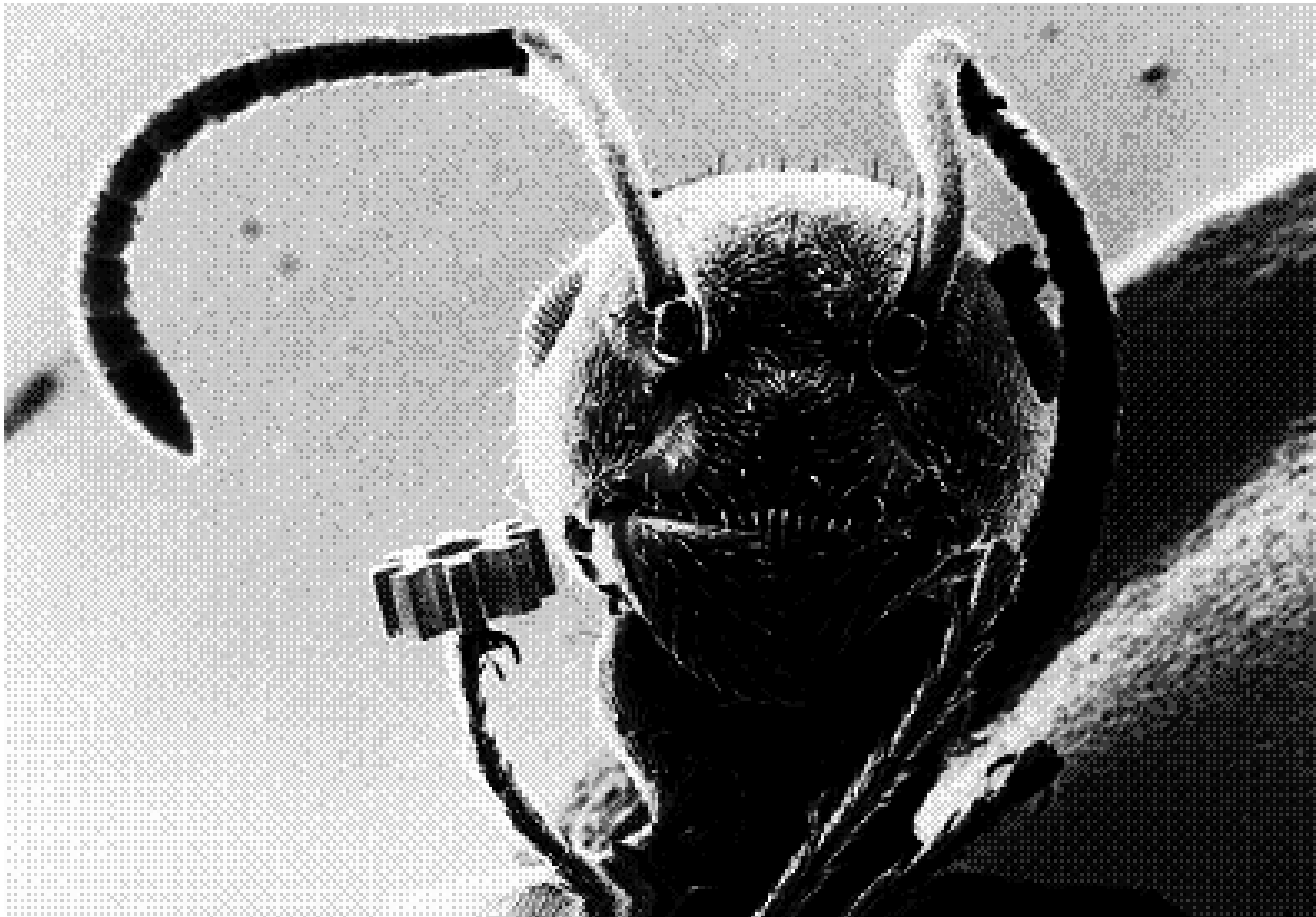
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Abstract		
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Tools for Ants?



From *Scientific American*, November 1992

Microelectromechanical Systems

Sensors

physical

chemical

biological

Mechanisms

beams

diaphragms

suspensions

springs

gears

linkages

thin films

microtubes

Actuators

resonators

valves

pumps

motors

mirrors

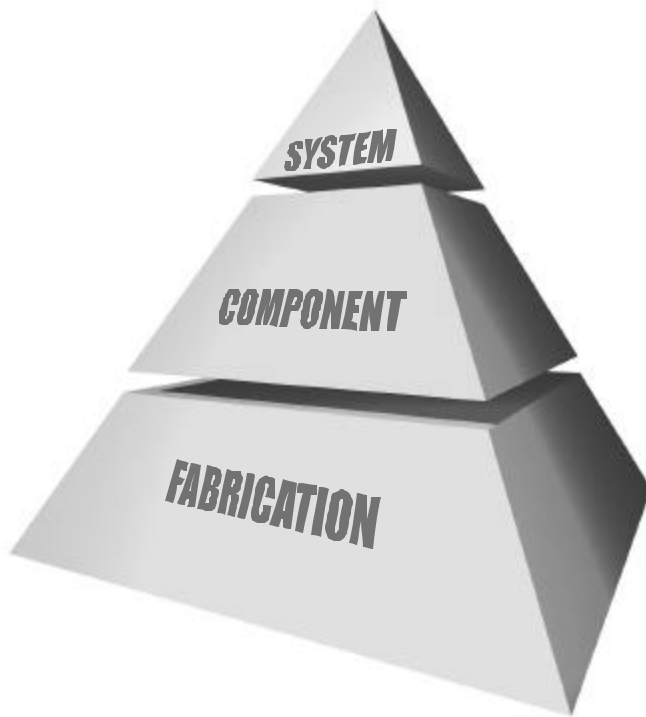
tweezers

Courtesy of M. Mehrengany
Case Western Reserve University

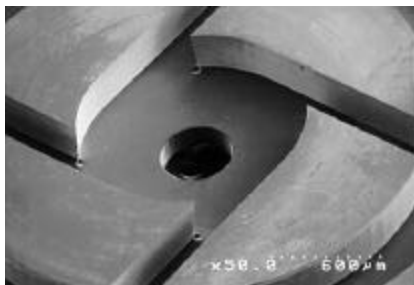
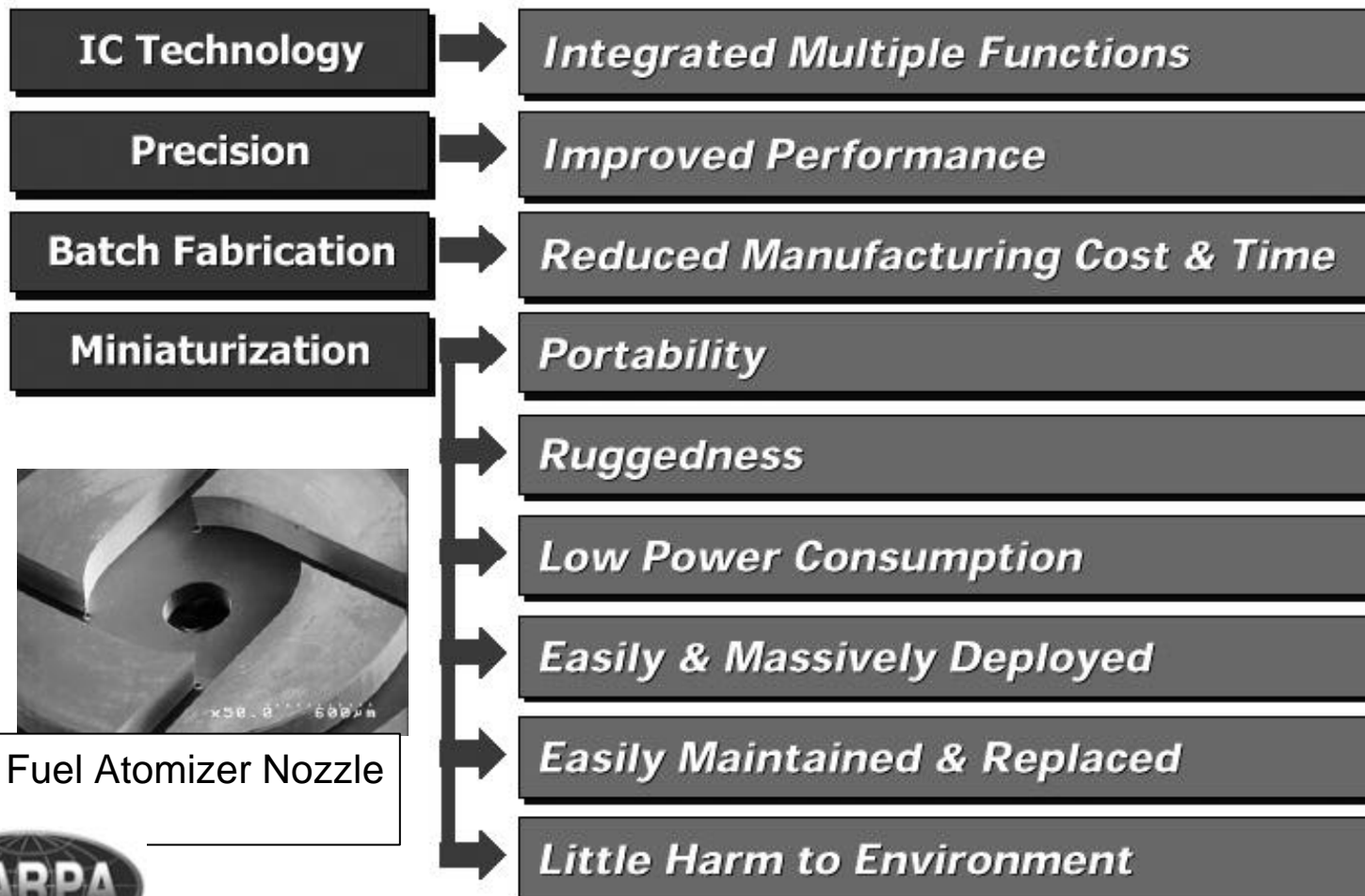
**MEMS merges computation with sensing and actuation
to change the way we perceive and control the physical world.**

MEMS – A Core Technology

- Micro-Electro-Mechanical Systems (MEMS) is a core technology that:
 - Leverages IC fabrication technology
 - Builds ultra-miniaturized components
 - Enables radical new system applications



Why Use MEMS?

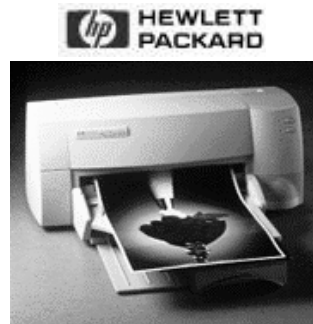
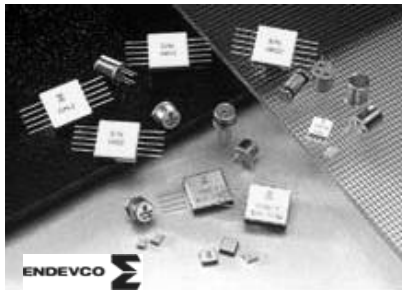


Fuel Atomizer Nozzle



Commercial Packaged MEMS

Microsensors



Print Cartridges



Microvalves



Pressure Sensors

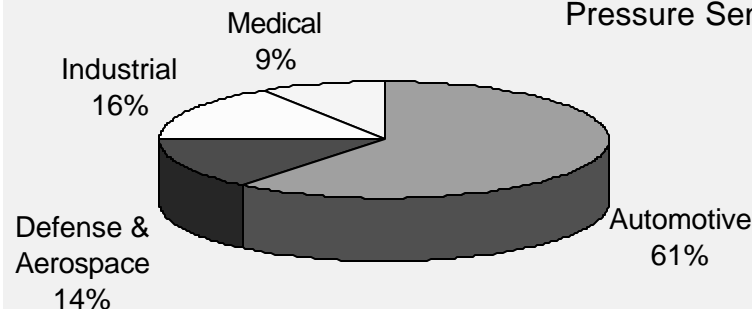


Accelerometers



Microfluidics

Major Segments



"U.S. MEMs-Based Sensor Markets"
Frost & Sullivan Report # 5999-32, 1999



Projectors

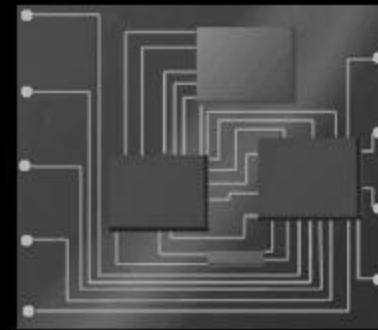
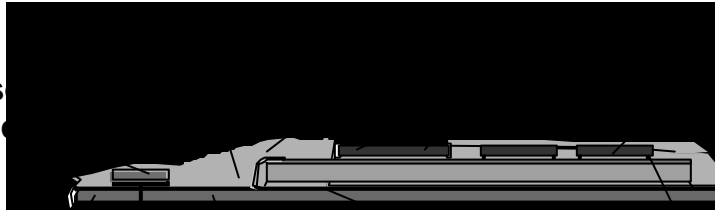
Pressure Sensor Belt on Jet Planes

Pressure Belt Cross Section

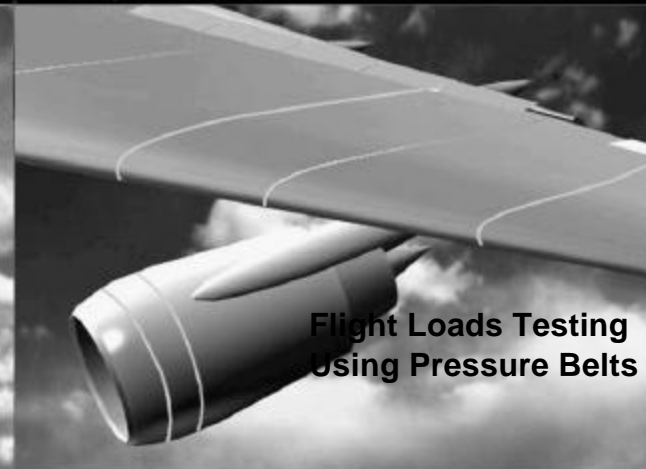
MEMS Sensor Integrated on an MCM with Embedded Passives

Inter-s
connec

End of
mod



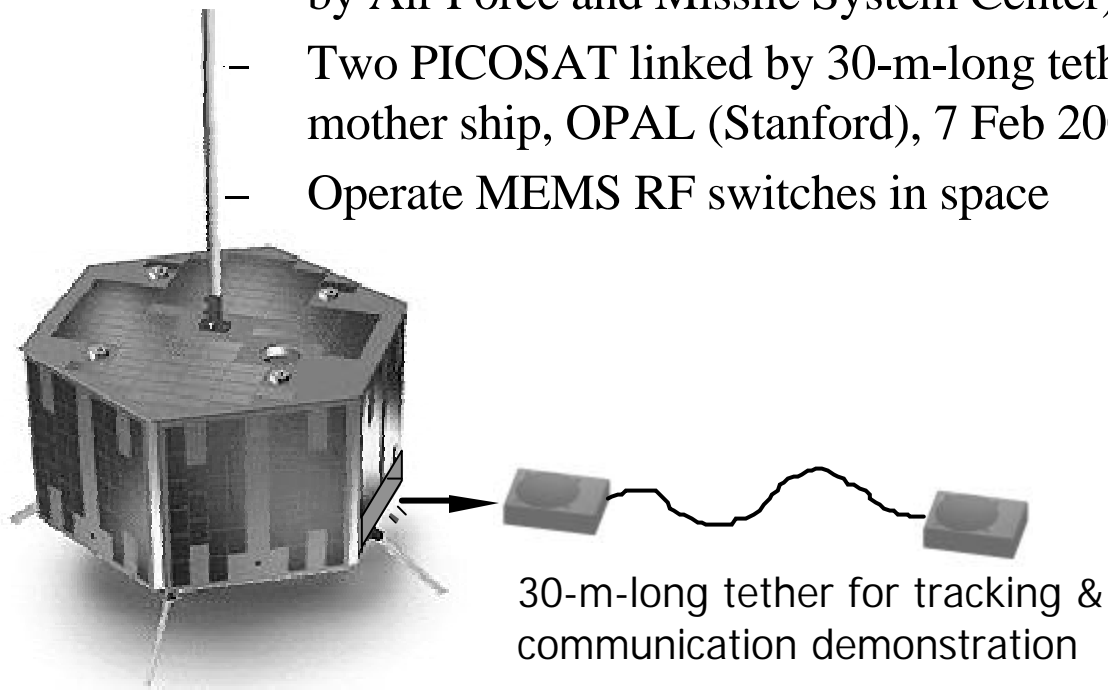
Boeing Pressure Belt Using MEMS



**Flight Loads Testing
Using Pressure Belts**

PicoSAT Aboard Stanford OPAL Satellite

- First demonstration:
 - Launched by first flight of Minotaur 26 Jan 2000 (sponsored by Air Force and Missile System Center)
 - Two PICOSAT linked by 30-m-long tether jettisoned from a mother ship, OPAL (Stanford), 7 Feb 2000
 - Operate MEMS RF switches in space



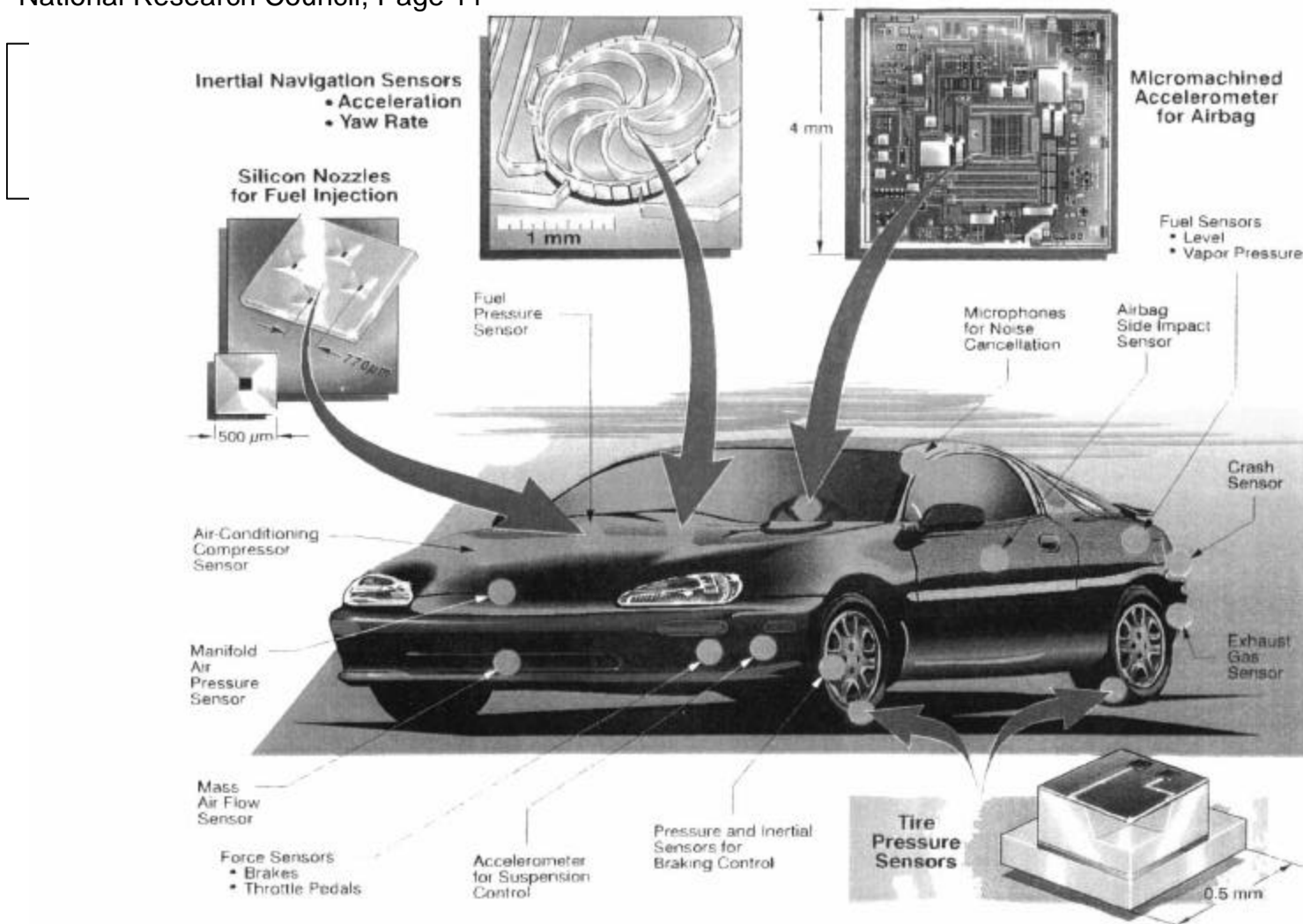
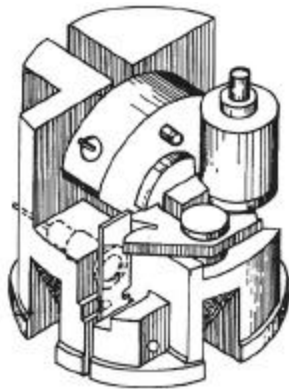


Figure 1-8: Concepts for applications of automotive sensors and accelerometers. MEMS could be used to activate suspension systems, control engines and emissions, control vibrations, and cancel noise. Source: D. Thomas, Perkin-Elmer Applied Biosystems, based on concepts by G. Kovacs, K. Petersen, and M. Albin.



Insertion of MEMS Technology In Fuze Safe & Arm

Conventional Mechanical S&As



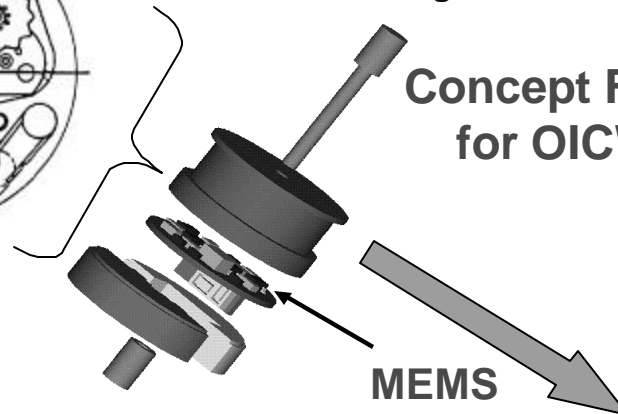
Missile

Artillery



This concept takes all the functions embodied in a conventional mechanical S&A and implements them in a single S&A die which is integrated with a fuze circuit board.

Concept Fuze for OICW



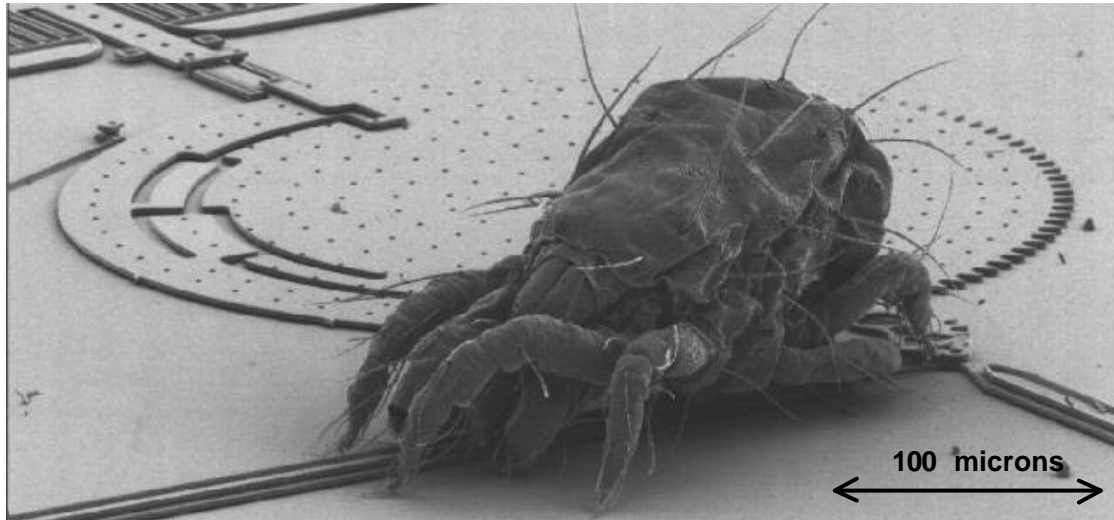
**MEMS
S&A die**

**FUZE ON
A CHIP**

Note: a MEMS mechanical S&A is not a “sensor” per se, but rather its components intrinsically combine both sense and actuate functions in a single unpowered chip.

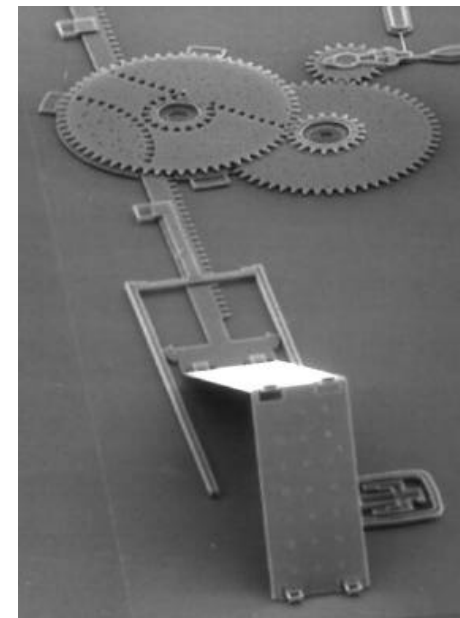
Committed To Excellence

MEMS are small...



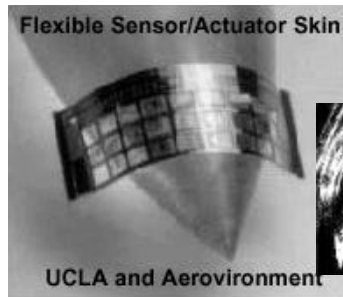
but not
insignificant!

Sandia MEMS
“strong-link” system
for Trident “C-4” RV
retrofit



Sandia National Laboratories
Intelligent Micromachine Initiative

MEMS for Ordnance



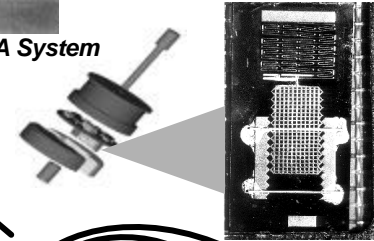
Active, conformal structures



INS Seeker detectors
IR, RF

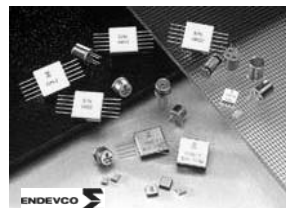
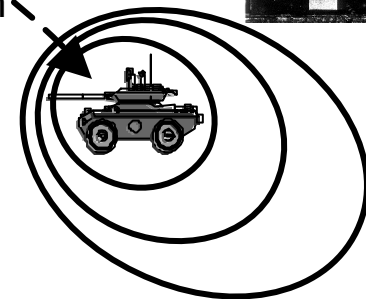


Fuze/safety and arming

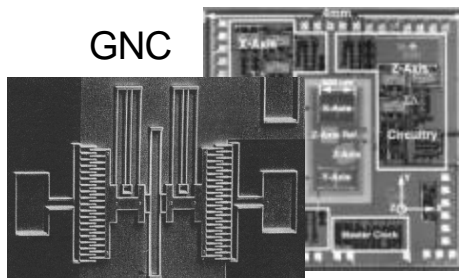


"This is a lesson we learned in Desert Storm and Kosovo. We cannot currently do as good a job as we would like on killing critical mobile targets on the battlefield."

Adm. Harold W. Gehman Jr,
former NATO Supreme Allied Commander Atlantic and
CINC Joint Forces Command



Environment &
Target Sensors



MEMS for the Land Warrior

Computer/Radio Subsystem

- Computer
- Soldier Radio
- Squad Radio
- GPS
- Handheld Flat Panel Display
- Video Capture

Protective Clothing and Individual Equipment Subsystem

- Advanced Load Carrying Capability
- Chem/Bio Garment/Glove/Boot
- Combat ID



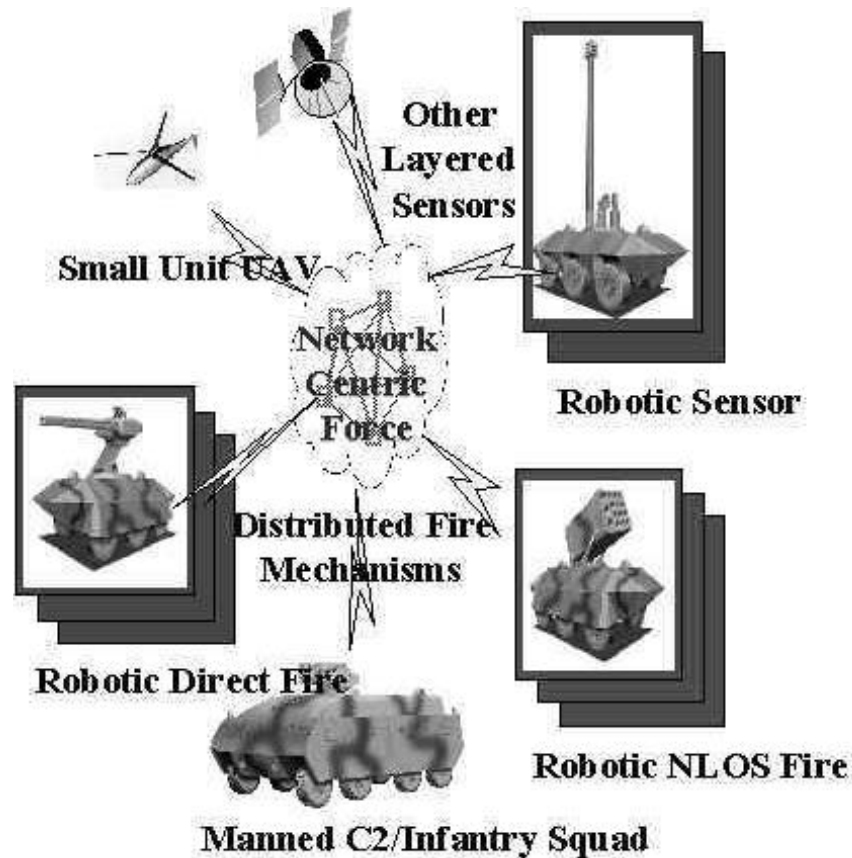
Integrated Helmet Assembly Subsystem

- Lightweight Helmet with Suspension
- Helmet-Mounted Display
- Image Intensifier
- Laser Detector
- Chem/Bio Mask
- Ballistic/Laser Eye Protection

Weapon Subsystem

- Laser Rangefinder
- Digital Compass
- Wiring Harness
- Video Camera
- Thermal Weapon Sight
- Close Combat Optic

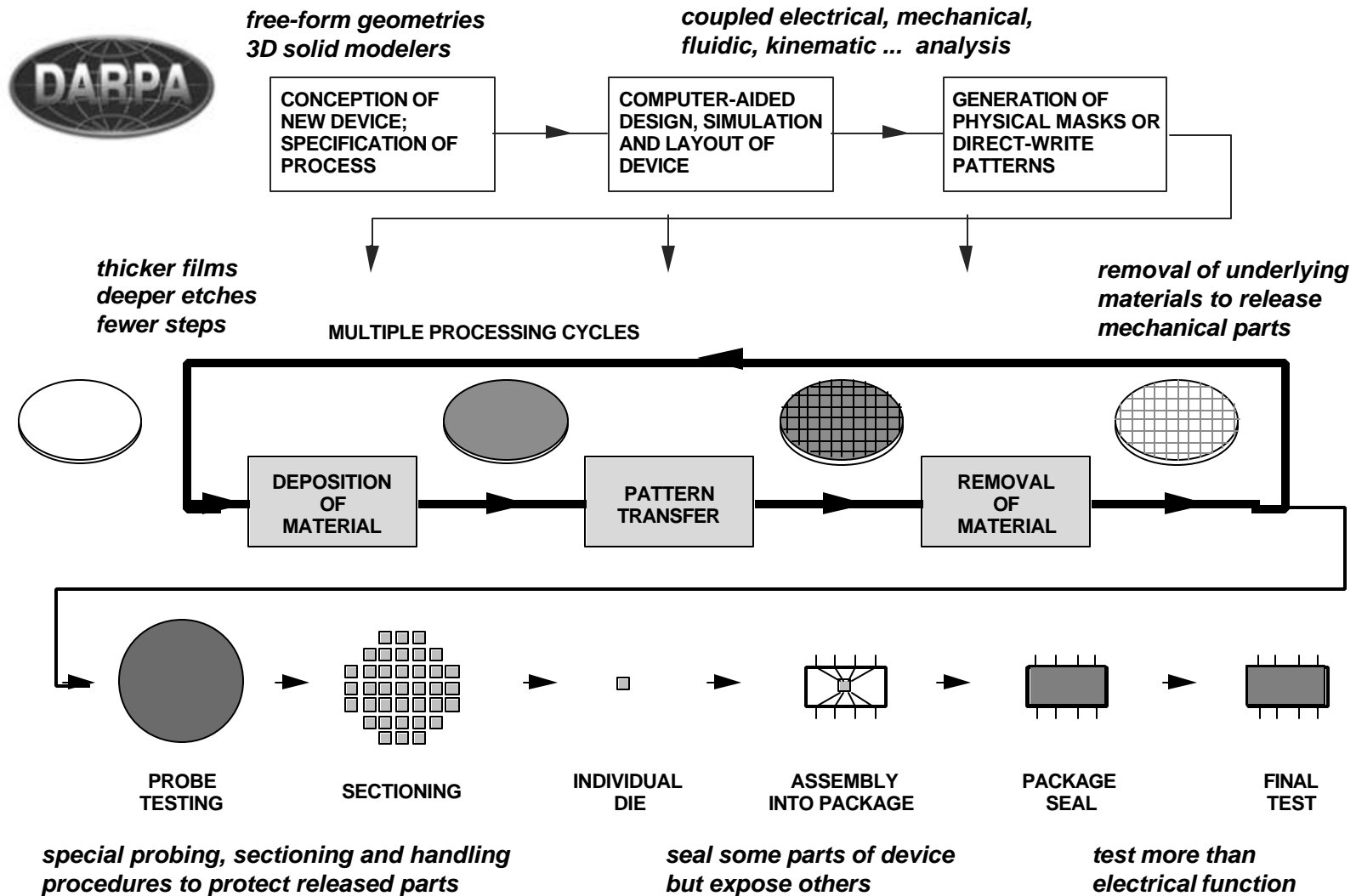
Future Combat Systems



- Army transformation to lighter, faster, more lethal, networked force
- Joint Army-DARPA program
- Deployment in 2012
- MEMS in sensor webs, active tags, munitions, MAVs, seekers, communications, power, ...

<http://www.darpa.mil/fcs/>

MEMS Builds on Microelectronics Manufacturing



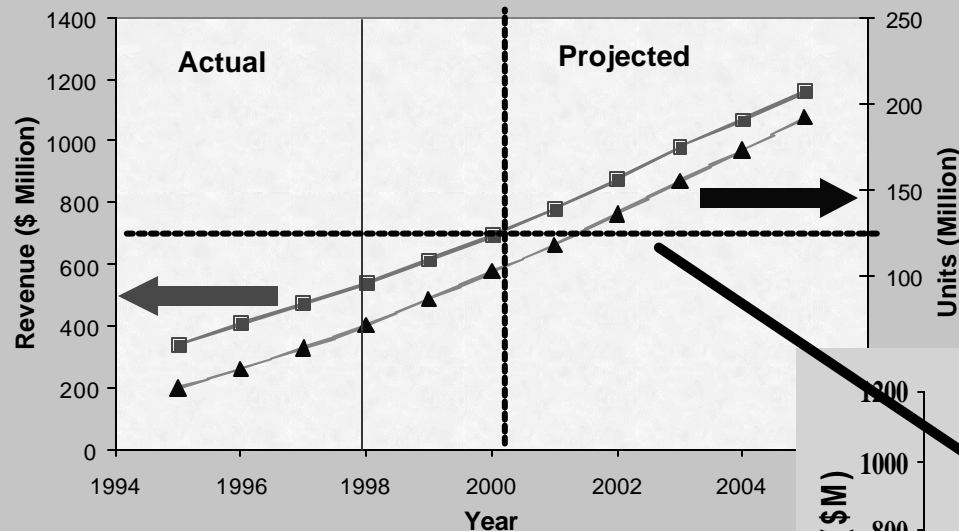


MEMS MANUFACTURE

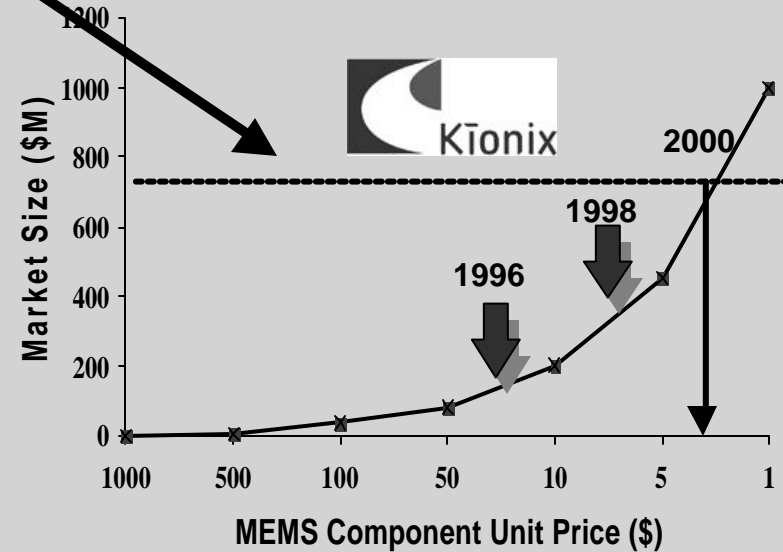
- **MEMS is projected to be a \$34 Billion World wide industry by year 2002**
 - **multiple commercial growth opportunities**
- **The MEMS Silicone (Si) based Industry is a spin-off of the Integrated Circuit (IC) Industry**
 - **Utilizes modified IC processes**
 - **Production lines tend to have fixed operating costs and are therefore volume sensitive**
 - **Inspection can be more item specific**
 - **Like IC's, smaller production could become sole source**

MEMS-Based Sensors

Market Summary



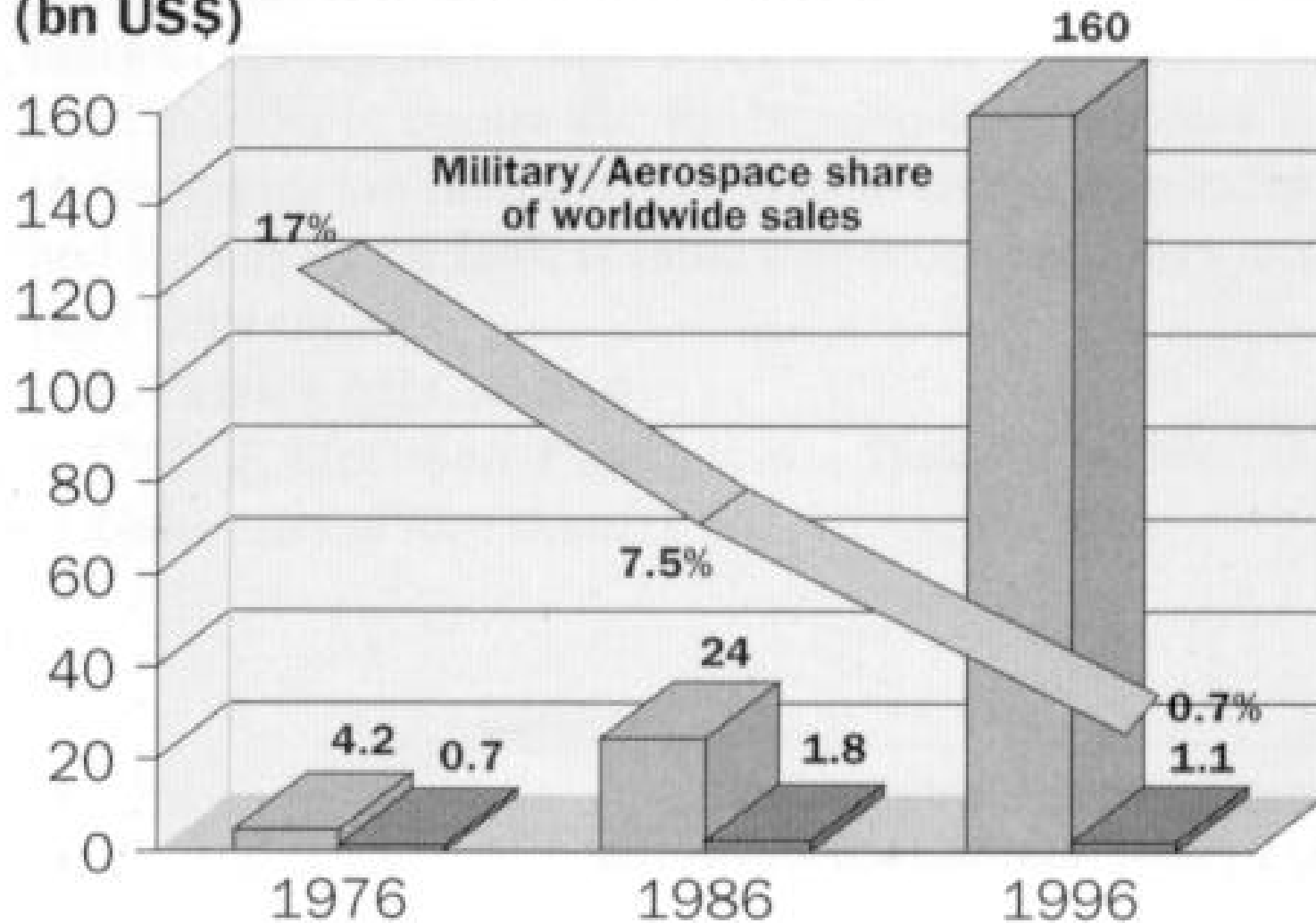
“U.S. MEMs-Based Sensor Markets”
Frost & Sullivan Report # 5999-32, 1999



Military Applications of MEMS

<u>ITEM</u>	<u>SENSORS/ITEM</u>	x	<u># ITEMS</u>	=	<u># SENSORS</u>
FACILITIES	2 10³		6 10²		10⁶
SATELLITES	10²		8 10²		10⁵
AIRCRAFT	2 10³		2 10⁴		10⁷
SHIPS & SUBS	3 10⁵		5 10²		10⁸
LAND VEHICLES	10²		10⁵		10⁷
PERSONNEL	3 10		3 10⁵		10⁷
COMM GEAR	10²		4 10⁵		10⁷
FIREARMS & GUNS	10²		5 10⁶		10⁹
<i>MUNITIONS</i>	10		10⁸		10⁹
<i>MISSILES</i>	10²		10⁵		10⁷
<i>TORPEDOES</i>	10²		8 10³		10⁶

Worldwide Semiconductor Sales (bn US\$)





MEMS MANUFACTURE

ECONOMICS

- Utilizing Facilities that are NOT fully work loaded -
 - Can be costly (Cost of setup & run plus profit)
 - Generally have lower yields
- Utilizing Facilities that are FULLY work loaded -
 - Continue to be costly (Cost of setup, run, plus value of profit lost due to interruption of high volume production)
 - High Volume = more than 200K / week)
 - Generally uninterested in small production quantities
 - not profitable to interrupt on-going high volume Production



MEMS MANUFACTURE

IRONY

- **High volume older fabrication houses have solved the problems of yield, stiction and areas that affect their ability to make a profit.**
 - **Information is considered proprietary and forms part of their competitive edge.**
- **Trying to estimate the impacts of these areas adversely affect Government cost projections**
 - **In most cases Government quantities are too small to interest the large fabrication houses.**



MEMS MANUFACTURE

DESIGNER'S DILEMMA

- **Prototype houses take too long to fabricate and produce low yields**
- **Production problems like stiction, yield, variation across the wafer, etc. affect R&D programs and cost to field projections.**
- **Little or no reliability data is available**
- **Small fabrication houses do not have the resources to do all the science and engineering needed to resolve these common problems.**



MEMS MANUFACTURE

OPTIONS

- **Let the marketplace handle the problems**
 - **End up with Item specific solutions**
 - **Delayed implementation of new items**
 - **Creates multiple small sole source situations**
- **DOD/Weapons Systems Industry –**
 - **provide support for the establishment of a MEMS Design, Reliability & Manufacturing database.**
 - **Group technology approach to system designs**
 - **Consider a CRADA w/ MEMS Industry to find processing solutions to making low rate production affordable and profitable**



Conclusion

- **MEMS will continue to grow probably similar to IC's**
- **MEMS will integrate with micro and Nano electronics to provide today's complicated electromechanical systems on a single chip.**
- **MEMS could greatly affect the DOD systems by providing Sensor and activator systems with little affect on the parent system.**
- **MEMS Industry will also follow the IC path in its inability to meet our needs unless we help the industry establish cost effect and profitable low rate production techniques or develop methods to increase the volume for the individual devices.**



Recommendations

- **Use Commercial Off-The-Shelf (COTS) components wherever feasible**
- **Limit MEMS device development to 1 or 2 designs to be used across multiple product lines. Modify these designs and their electronics to meet specific application needs.**
- ***Establish a Joint Military/Industry Oversight Committee to monitor the requirements and applications for MEMS devices in weapons and ammunition and develop processes to economically produce reasonably small quantities.***
 - **Form an Integrated Product Team (IPT)**
 - **Pursue CRADAs w/Munition & MEMS Industries**



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